Con-X Reflection Gratings: Process Development Updates

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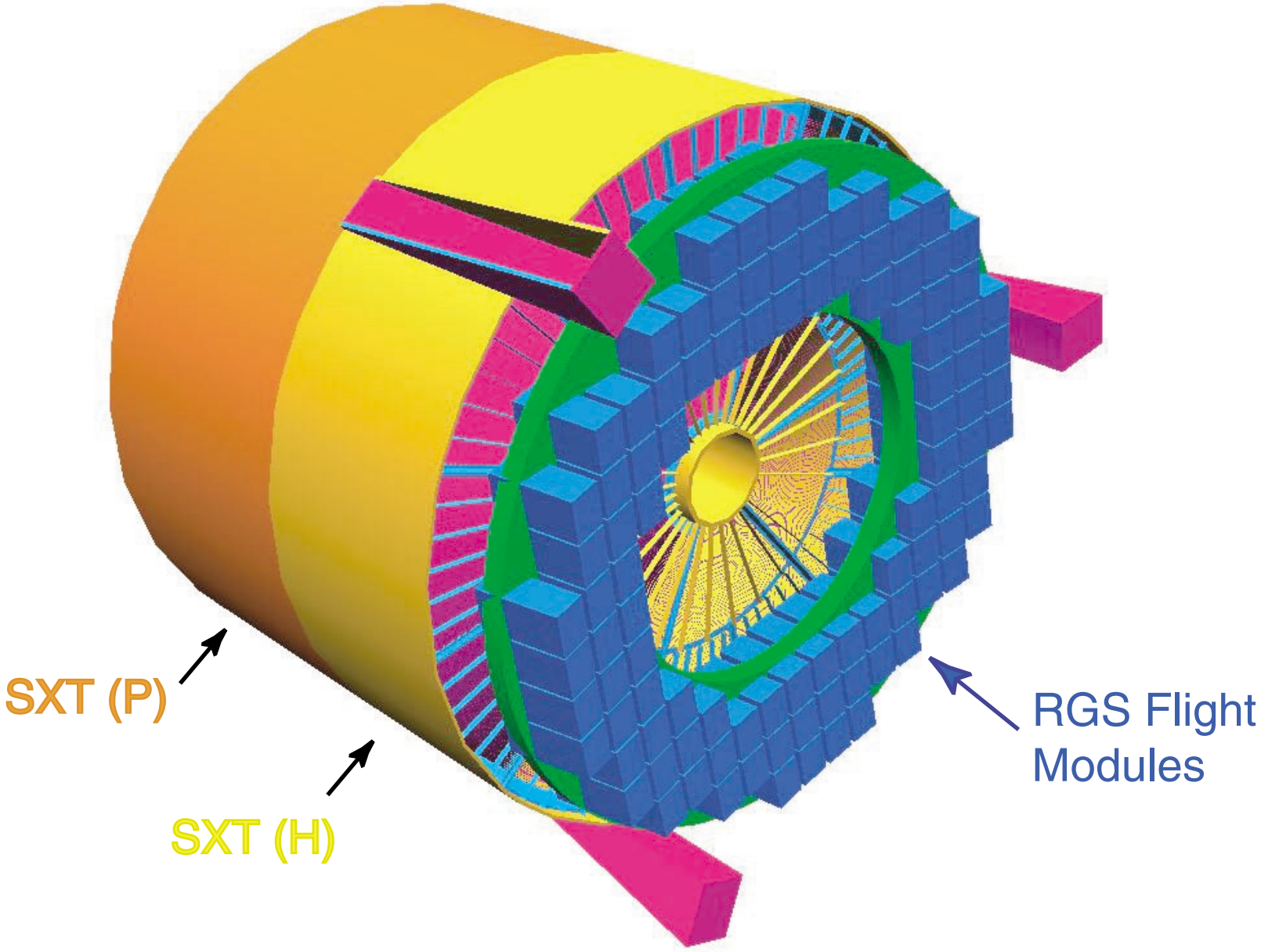
Results:

- Improved Microcomb Fabrication Process

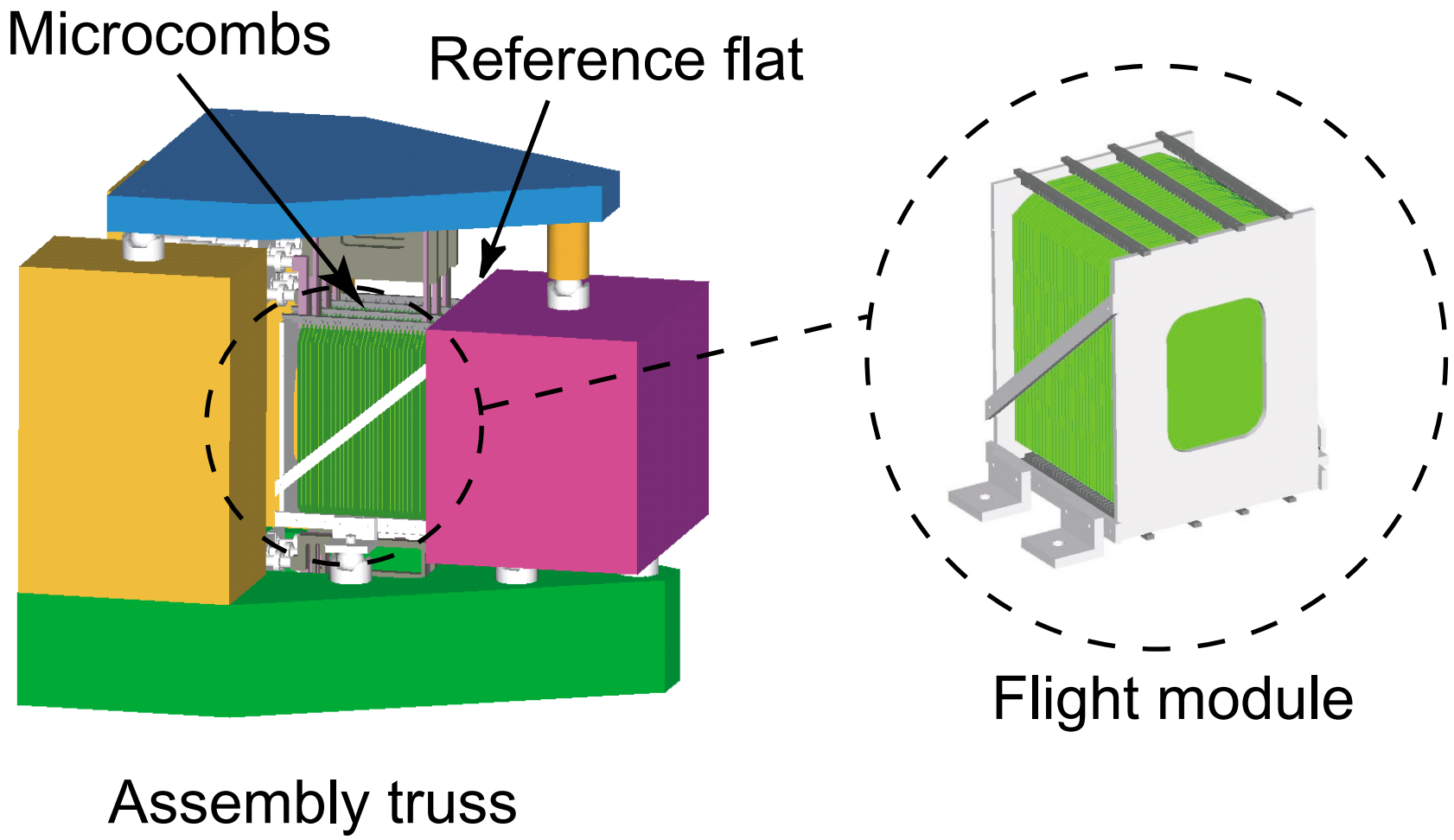
- Patterned Large Area Gratings (300 cm Ø)

- Developed Blazed Gratings
  for Off-Plane Geometry

Constellation-X Optics Concept

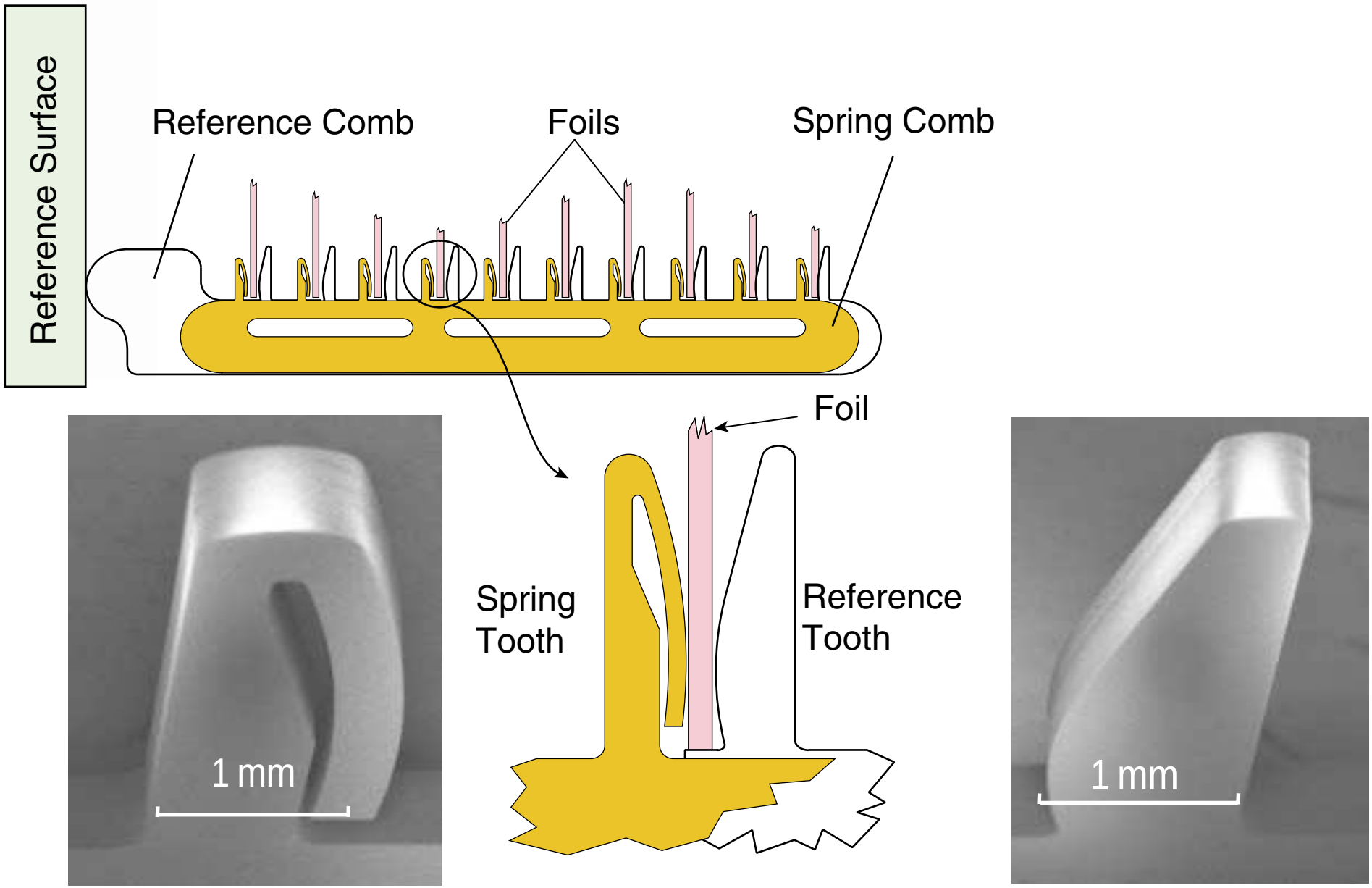


Modular Assembly



Currently ~ 1/3 micron (< 1 arcsec) positioning repeatability

Silicon Microcombs Establish Accurate Metrology Frame



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Microcomb Fabrication Challenges: Process Uniformity and Repeatability

Solution: New BOX Wafer Double-sided Etching Process

(a) BOX silicon wafer, device layer 100(1) μm; handle layer 350(5) μm; BOX 2 μm

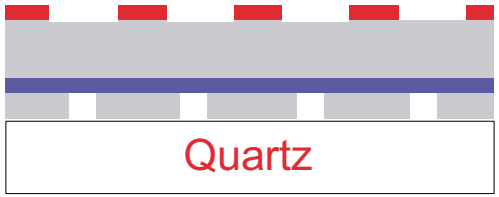
(b) Pattern Photoresist (PR) on the device layer.

(c) Deep Reactive Ion Etch (DRIE) device layer.

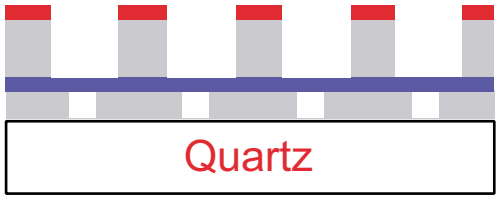
(d) Clean wafer.

(e) Pattern PR on the handle layer.

(f) Attach wafer to quartz handle-wafer.

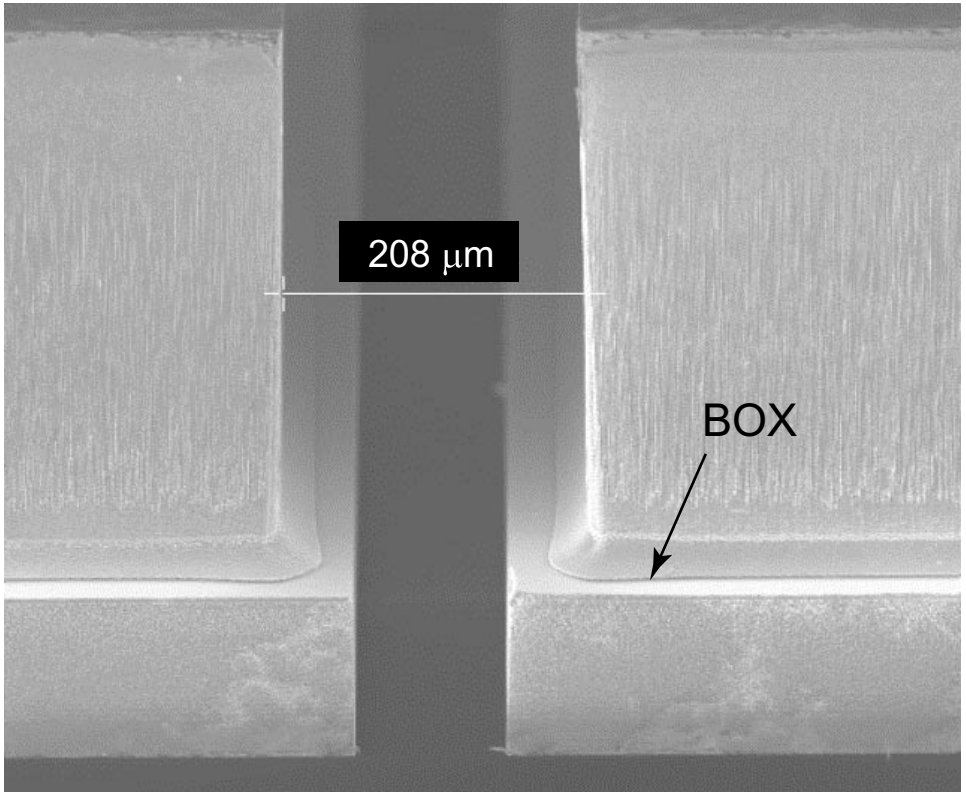


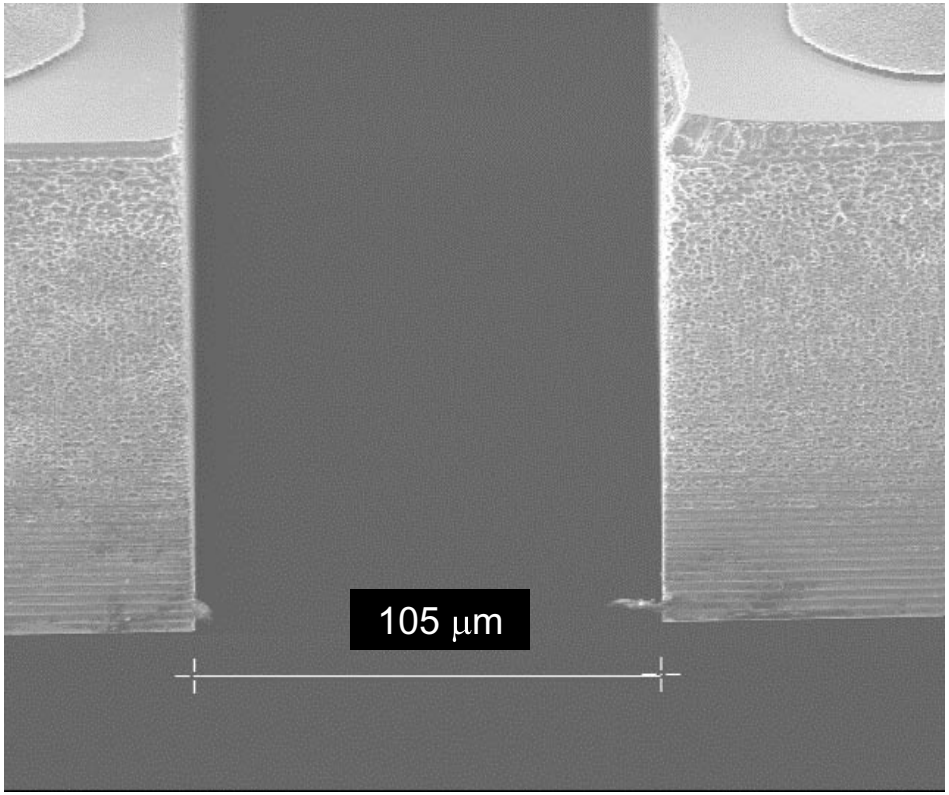
(g) DRIE handle layer (100 min plus 10 minutes over-etching).



(h) Dismount wafer, BOE to strip the BOX layer, clean the wafer.

SEM Images of BOX Double-sided Etching Results





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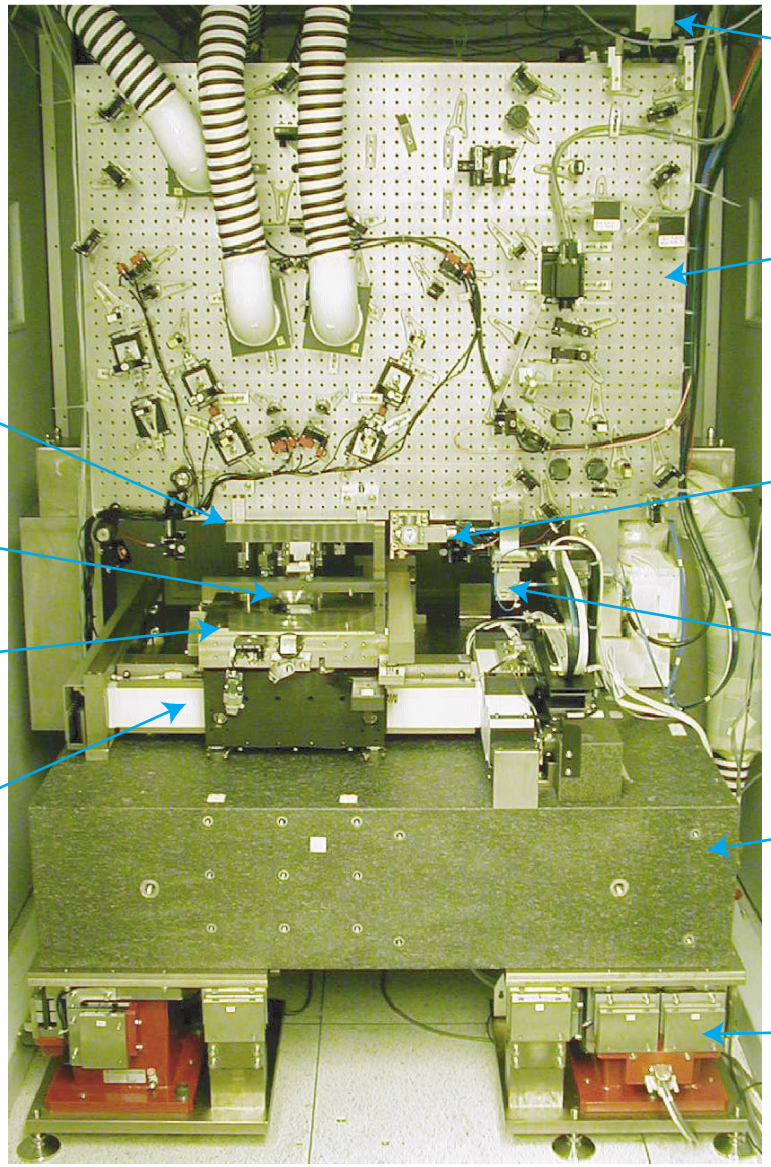
The Nanoruler - A Scanning Beam Interference Lithography Tool



Receiving tower for UV laser (λ = 351.1 nm)

Optical bench with interference lithography optics

Refractometer interferometer

X-axis interferometer

Granite base

Isolation system

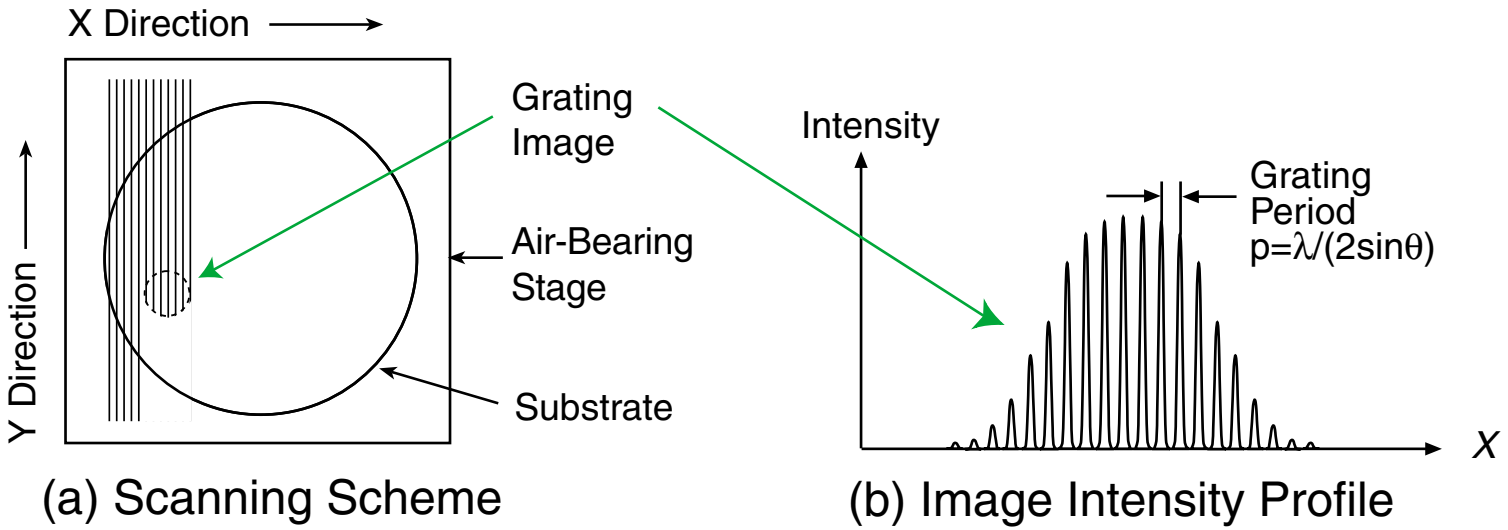
Metrology block with phase measurement optics

Wafer

Chuck

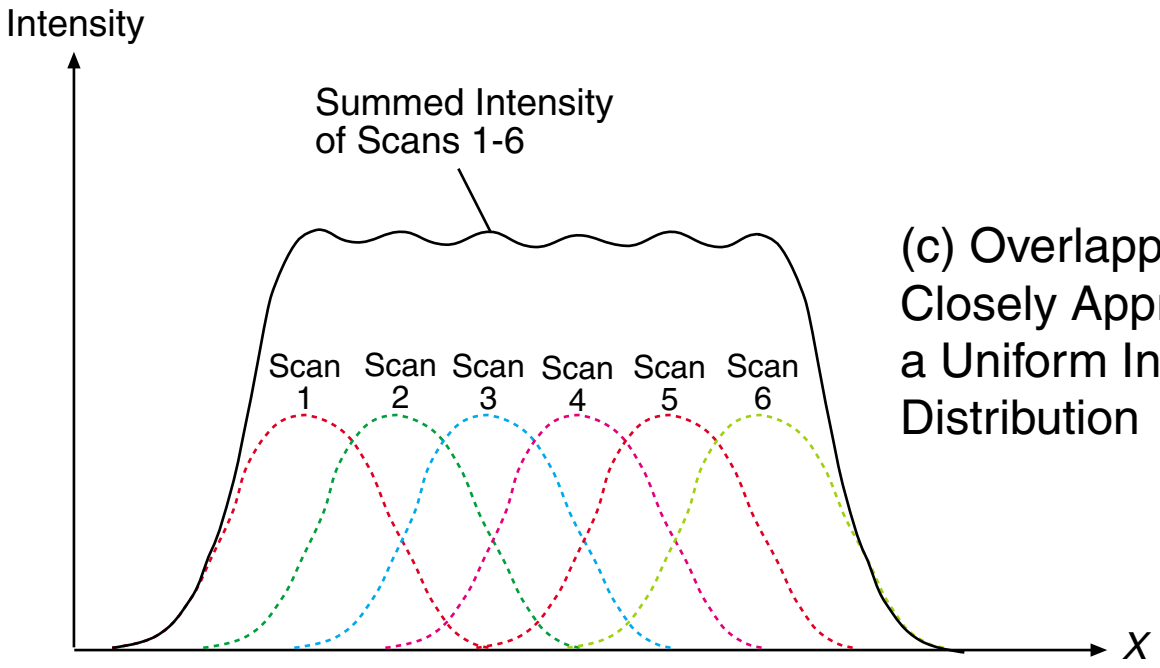
X-Y air bearing stage

Grating Scanning Method



(a) Scanning Scheme

(b) Image Intensity Profile



(c) Overlapping Scans Closely Approximate a Uniform Intensity Distribution

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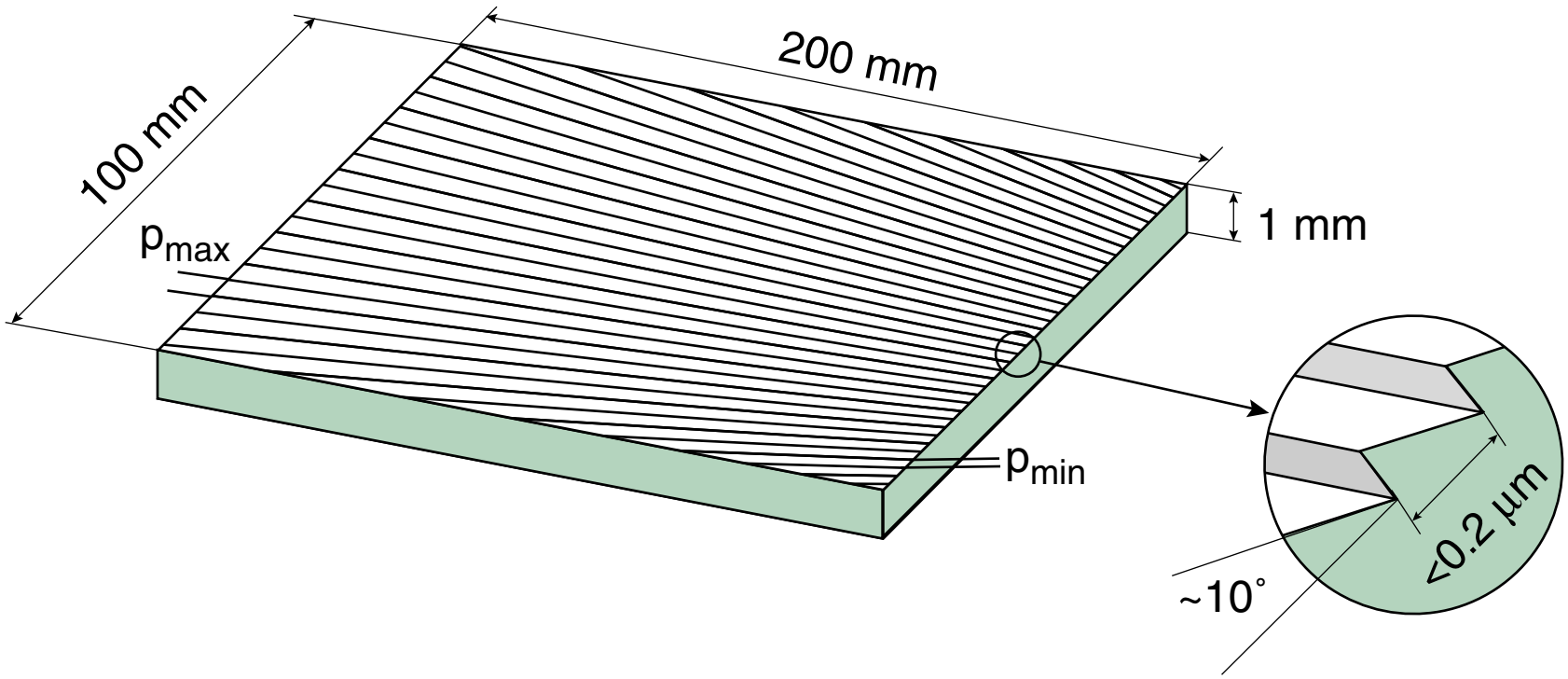
X-ray Reflection Grating Geometry
(Off-Plane Diffraction)



p_{ave} <0.2 μm

Chirp Δp/p ~2%

Blaze ~10˚

Flatness <1.0 μm

Roughness <0.5 nm

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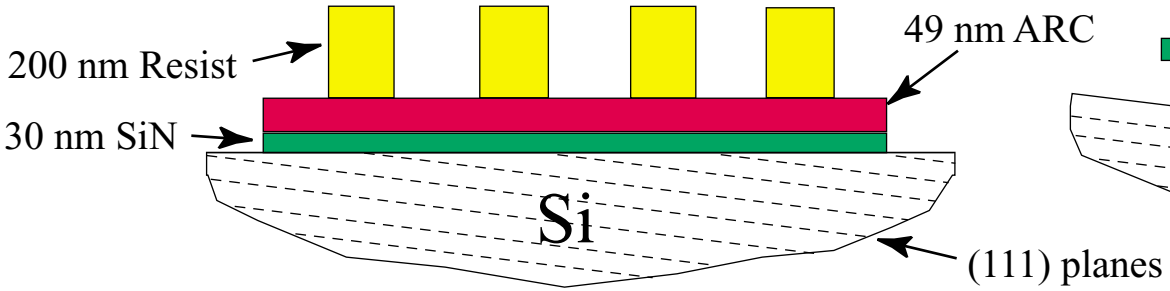
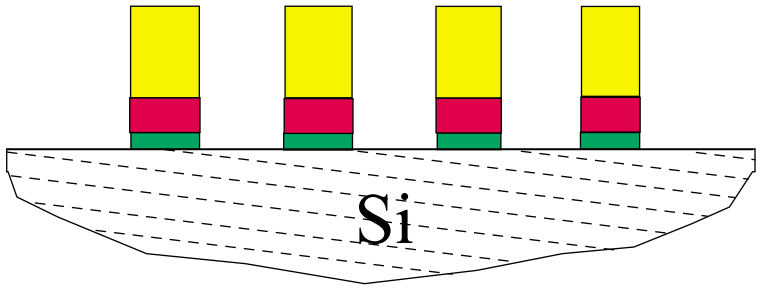
Super-Smooth Blazed Reflection Gratings From Miscut Silicon

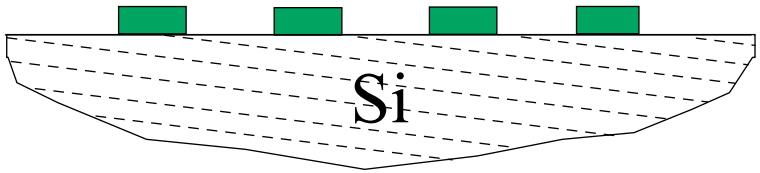
1. Coat with bilevel resist and pattern gratings.



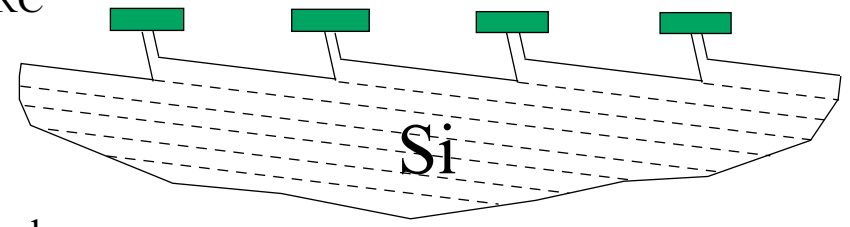
2. Plasma etch ARC and nitride.



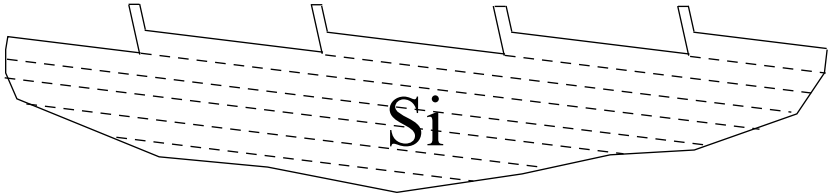
3. RCA clean.

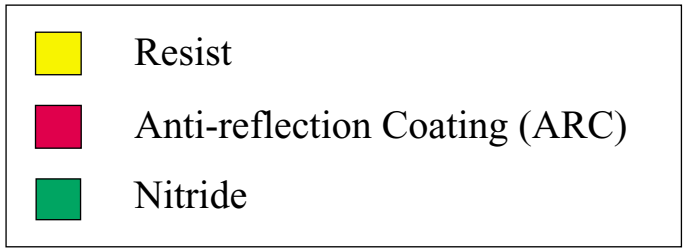


4. Anisotropic KOH etch.

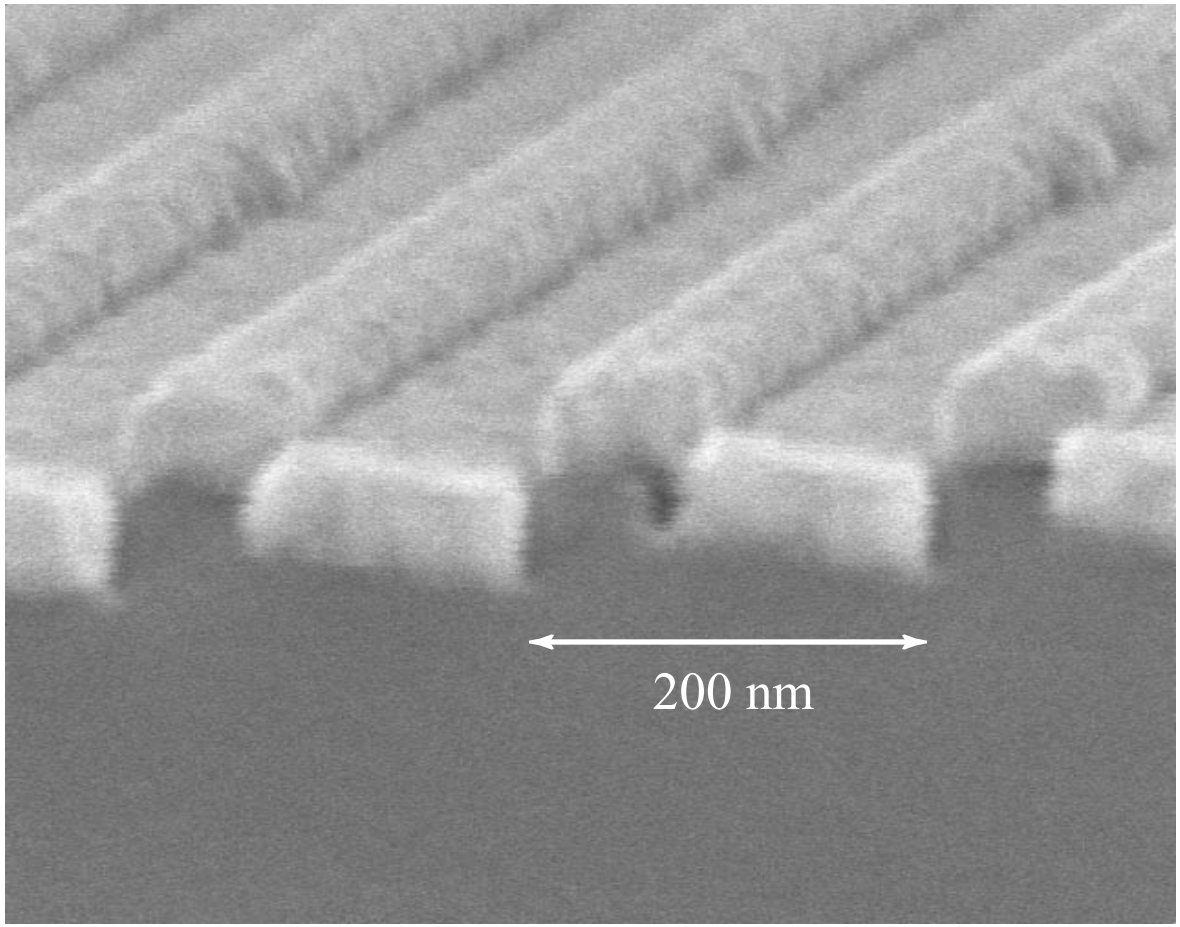


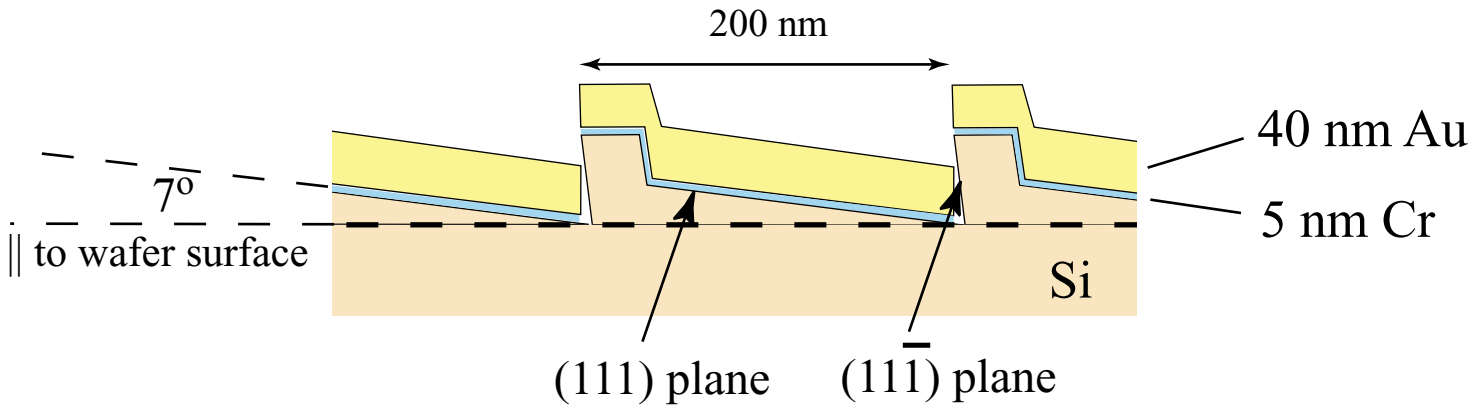
5. Remove nitride with HF.





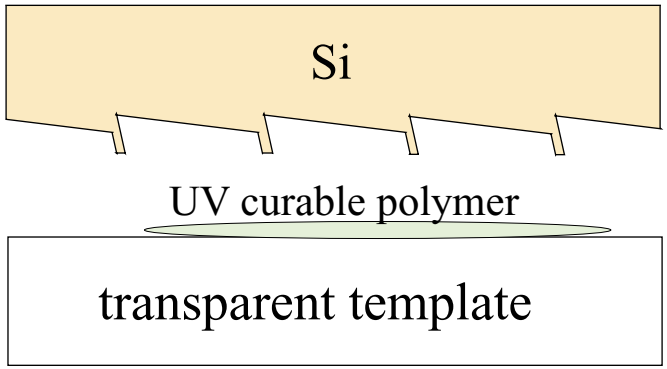
SEM of Blazed Off-Plane Grating



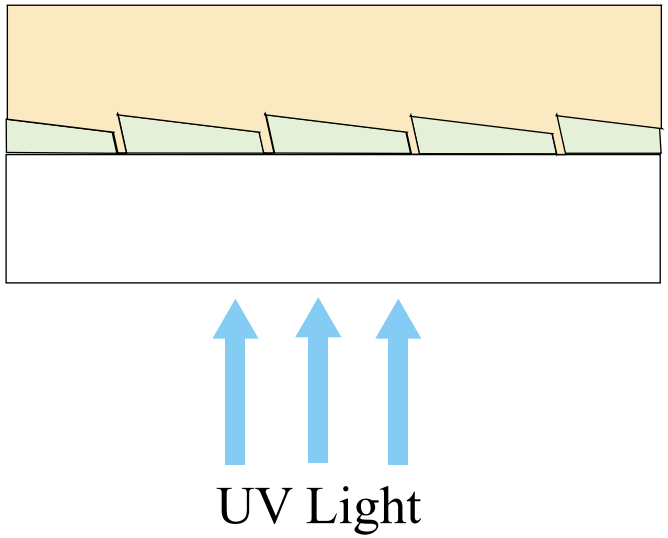


Grating Replication From Silicon Master

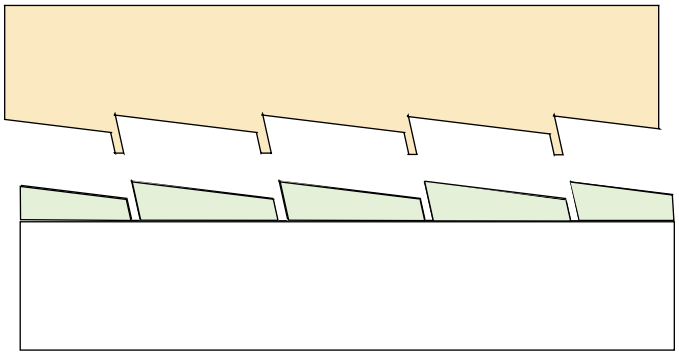
1. Add polymer to the surface



2. Close the gap, cure polymer with UV light



3. Remove mold

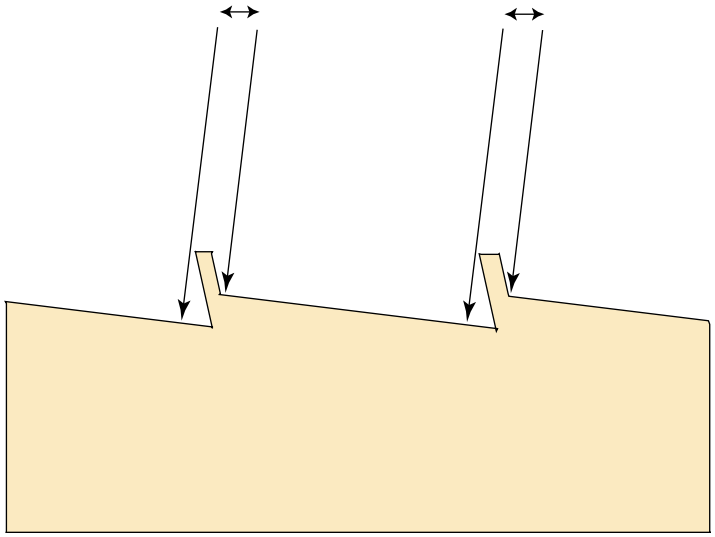


- cheaper
- boosts efficiency?

Off-Plane Grating Effective Area

Si master:

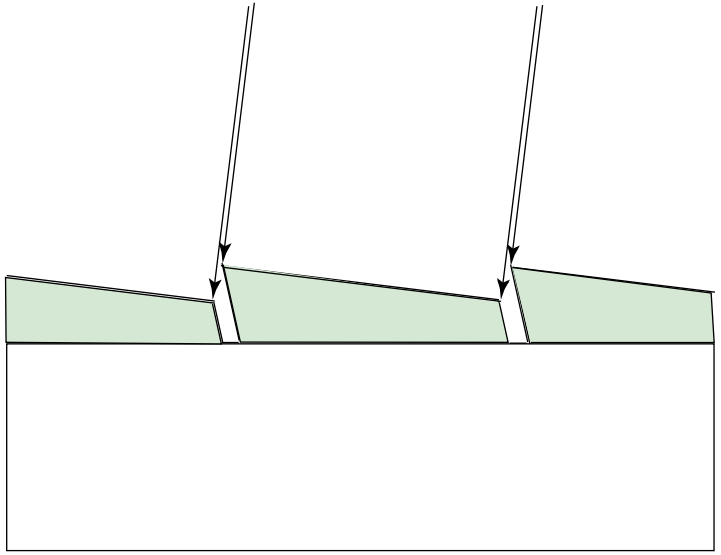
- area covered by "nubs" lost



"nubs" can be removed with additional processing steps

Replica:

- area loss negligible



quality of replicated surfaces?

Summary of Milestones

Double-sided etch process for alignment structures (microcombs)

- higher yield
- larger wafers, longer combs
- higher accuracy

Nanoruler enables large area gratings (> 300 mm)

- 3 nm phase control
- sub-nm linewidth control
- future variable period capability ("chirp")

Super smooth blazed off-plane gratings from miscut silicon wafers are feasible